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Study of human exposure to fine particulates and respiratory tract depositions in residents of an industrial environment in India

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This paper estimates personal exposure to particulate matter (PM), deposition and status of selected toxic metals in respiratory tract washout samples obtained from 20 humans residing in township of an industrial environment in central India. All humans samples for personal PM exposure and respiratory tract depositions, collected during winter season, were analyzed for selected toxic elements (Pb, Cr, Cd, Co and Ni). Personal PM_5 exposure levels were found between 2.6-48.6 µg/m^3 for various categories. Chemical analysis of PM samples shows that higher risk is associated with housewives who spend their time (> 85%) indoors. Good positive correlation coefficient value is found for PM concentrations and respiratory tract depositions.

Keywords: Human exposure, Particulate matter, Respiratory tract depositions, Toxic elements

Introduction

Adverse effects of particulate matter (PM) on human health include not only premature mortality from acute pollution episodes, but also aggravation of existing respiratory and cardiovascular disease, damage to lung tissue, impaired breathing and respiratory symptoms, and alterations to the body's physical and immune system defenses against inhaled particles[1–3]. Pollutants enter body through respiratory system. Lungs contain several hundred millions small sacs (alveoli), which provide a surface area (50 m^2) for exchange of gases. An average adult breathes approx. 30 pounds of air per day[4,5].

This paper estimates personal exposure to particulate matter (PM), deposition and status of selected toxic metals in respiratory tract washout (RTW) samples of 20 humans residing in Varanasi (UP) of an industrial environment in central India.

Materials and Methods

Subject Selection

A questionnaire, prepared for human subjects, included daily routine, total time spent in various environments, types of job, age, sex etc. PM samples were collected from 20 human subjects, which were divided into three categories: Category-A, adult male / female who spend < 14 h indoors; Category-B, children who spend on an average 18 h indoors; and Category-C, housewives who spend > 20 h indoors (Table 1).

Personal PM Sampling

Human subjects (20) for personal PM monitoring were sampled on 12 h basis. During this period, subjects were allowed to pass through various microenvironments such as homes, traffic environments, offices, schools, playgrounds etc. Personal respirable dust sampler (Envirotech APM 801) was used for personal PM monitoring. Instrument was worn on collar/ lapped of subjects. Sampling was performed by following standard conditions of operation. Five samples were collected from each subject in alternate days.

Respiratory Tract Washout Samples

From same 20 subjects, RTW samples were collected using a fibre optics bronchioscope (Olympus, Modal BF-XT20) with attached camera and brush just after the completion of personal PM_5 sampling. Sites of bronchii were screened and brushed, and RTWs (10 ml) were collected from each subject. Brush containing scraped deposits was dipped into 40 ml saline (0.9% NaCl

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Table 1—Subjects selected for study

Category-A			Category-B			Category-C		
Sub. No.	Age	Sex	Sub. No.	Age	Sex	Sub. No.	Age	Sex
A_1	24	M	B_1	12	M	C_1	46	F
A_2	46	M	B_2	13	M	C_2	52	F
A_3	19	M	B_3	9	M	C_3	32	F
A_4	34	M	B_4	10	M	C_4	29	F
A_5	39	M	B_5	10	F	C_5	40	F
A_6	29	F	B_6	14	F	C_6	21	F
A_7	23	F				C_7	22	F

M, male; F, female

Table 2—Personal exposure to PM toxic-load (μg/m^3) of subjects

Sub. No.	n	Personal PM_5	Pb	Cr	Ni	Co	Cd
Category-A							
A_1	5	6.3 ± 2.3[a]	0.96 ± 0.33	0.03 ± 0.01	0.02 ± 0.01	BDL	BDL
A_2	5	5.3 ± 1.1	0.41 ± 0.18	0.04 ± 0.01	0.02 ± 0.01	BDL	BDL
A_3	4	8.2 ± 4.0	0.21 ± 0.13	0.04 ± 0.01	0.03 ± 0.01	BDL	BDL
A_4	5	2.6 ± 0.9	0.08 ± 0.03	0.05 ± 0.01	0.01 ± 0.01	0.01 ± 0.01	BDL
A_5	5	9.3 ± 0.7	0.02 ± 0.02	0.06 ± 0.02	0.04 ± 0.02	0.01 ± 0.01	BDL
A_6	5	4.3 ± 1.8	0.63 ± 0.11	0.05 ± 0.03	0.01 ± 0.01	0.01 ± 0.01	BDL
A_7	4	5.5 ± 3.6	0.22 ± 0.08	0.01 ± 0.00	BDL	BDL	BDL
Average		5.93 ± 2.10	0.36 ± 0.13	0.04 ± 0.02	0.02 ± 0.00	0.01 ± 0.01	-
Category-B							
B_1	5	12.3 ± 4.4	0.18 ± 0.04	0.07 ± 0.02	0.05 ± 0.02	0.02 ± 0.02	BDL
B_2	5	16.5 ± 6.3	0.16 ± 0.07	0.09 ± 0.05	0.06 ± 0.04	0.03 ± 0.03	BDL
B_3	3	18.9 ± 3.5	0.26 ± 0.14	0.11 ± 0.07	0.09 ± 0.03	BDL	BDL
B_4	5	23.2 ± 7.9	0.35 ± 0.18	0.18 ± 0.10	0.12 ± 0.07	BDL	0.05 ± 0.04
B_5	4	4.5 ± 0.6	0.51 ± 0.33	0.05 ± 0.02	0.04 ± 0.04	0.04 ± 0.04	0.01 ± 0.01
B_6	5	3.5 ± 0.3	0.14 ± 0.05	0.03 ± 0.01	0.06 ± 0.03	0.01 ± 0.01	0.01 ± 0.01
Average		13.15 ± 4.64	0.27 ± 0.11	0.09 ± 0.03	0.07 ± 0.02	0.03 ± 0.03	0.02 ± 0.02
Category-C							
C_1	4	20.1 ± 6.3	0.01 ± 0.01	0.13 ± 0.08	0.18 ± 0.12	BDL	BDL
C_2	5	35.3 ± 7.5	0.01 ± 0.01	0.08 ± 0.02	0.06 ± 0.05	0.05 ± 0.04	0.02 ± 0.02
C_3	5	41.2 ± 16.3	0.21 ± 0.06	0.90 ± 0.45	0.19 ± 0.11	0.05 ± 0.02	BDL
C_4	5	9.3 ± 1.1	BDL	0.03 ± 0.02	0.01 ± 0.01	0.10 ± 0.04	0.04 ± 0.02
C_5	3	33.8 ± 10.8	BDL	0.12 ± 0.06	0.05 ± 0.04	0.04 ± 0.03	BDL
C_6	5	48.6 ± 23.6	0.14 ± 0.07	0.09 ± 0.03	0.01 ± 0.01	BDL	BDL
C_7	5	29.5 ± 7.7	0.06 ± 0.02	0.10 ± 0.05	BDL	0.03 ± 0.02	BDL
Average		31.11 ± 13.39	0.09 ± 0.04	0.21 ± 0.09	0.08 ± 0.04	0.05 ± 0.03	0.03 ± 0.02

Category-A, adult male/female who spend < 14 h indoor; Category-B, children who spends on an average 18 h indoors; Category-C, housewives who spends > 20 h indoors.
[a]GM (geometric mean) + SD(standard deviation); n, Number of measurements; BDL, below detection limits

Table 3—Toxic metal status in respiratory tract (μg/50 ml of washouts) in the subjects

Subject	n	Pb	Cr	Ni	Co	Cd
Category-A						
A_1	5	12.54 ± 8.11[a]	5.30 ± 3.22	4.34 ± 2.01	BDL	BDL
A_2	5	15.30 ± 4.32	4.97 ± 2.35	2.00 ± 1.22	BDL	BDL
A_3	4	26.60 ± 13.38	12.34 ± 5.51	6.30 ± 2.08	BDL	BDL
A_4	5	13.44 ± 5.51	8.80 ± 4.51	4.31 ± 0.81	0.80 ± 0.23	BDL
A_5	5	9.30 ± 4.65	6.44 ± 0.84	1.20 ± 0.65	0.11 ± 0.08	BDL
A_6	5	4.12 ± 0.84	3.70 ± 1.21	2.30 ± 0.49	0.95 ± 0.36	BDL
A_7	4	6.41 ± 2.31	4.40 ± 0.84	BDL	BDL	BDL
Average		12.46 ± 63.32	6.54 ± 2.31	3.40 ± 1.61	0.62 ± 0.28	-
Category-B						
B_1	5	5.60 ± 2.21	6.44 ± 2.11	4.44 ± 0.94	1.30 ± 084	BDL
B_2	5	6.93 ± 3.08	6.30 ± 4.21	3.20 ± 0.84	0.08 ± 0.03	BDL
B_3	3	7.60 ± 0.84	11.30 ± 5.51	4.35 ± 0.68	BDL	BDL
B_4	5	12.84 ± 8.54	13.33 ± 0.58	3.20 ± 3.01	BDL	0.08 ± 0.03
B_5	4	2.37 ± 0.52	5.50 ± 1.09	7.30 ± 4.22	0.85 ± 0.31	0.07 ± 0.04
B_6	5	0.81 ± 0.23	7.94 ± 2.20	2.37 ± 1.00	0.12 ± 0.08	0.01 ± 0.01
Average		6.09 ± 2.08	8.45 ± 2.31	4.12 ± 2.00	0.59 ± 0.31	0.05 ± 0.03
Category-C						
C_1	4	0.32 ± 0.11	7.80 ± 2.30	4.23 ± 0.81	BDL	BDL
C_2	5	0.95 ± 0.39	8.66 ± 2.31	4.20 ± 2.08	0.24 ± 0.12	0.22 ± 0.08
C_3	5	1.65 ± 0.41	16.50 ± 4.21	8.34 ± 5.51	0.84 ± 0.39	BDL
C_4	5	4.60 ± 1.00	19.63 ± 13.31	16.37 ± 9.51	1.50 ± 0.91	0.20 ± 0.07
C_5	3	3.60 ± 0.61	26.07 ± 18.31	13.07 ± 6.08	1.95 ± 0.84	BDL
C_6	5	0.09 ± 0.01	6.30 ± 2.30	2.60 ± 1.59	BDL	BDL
C_7	5	6.37 ± 4.51	7.85 ± 0.51	BDL	0.30 ± 0.08	BDL
Average		2.50 ± 1.51	13.23 ± 8.04	8.10 ± 3.21	0.97 ± 0.33	0.21 ± 0.08

Category-A, adult male/female who spend < 14 h indoor; Category-B, children who spends on an average 18 h indoors; Category-C, housewives who spends > 20 h indoors.
[a]GM (geometric mean) + SD(standard deviation); n, Number of measurements; BDL, below detection limits

solution). Screening and brushing was repeated till volume of saline solution increased from 40 to 50 ml.

Sample Preparation

Samples (50 ml each) were digested into a teflon digestion bomb using 10 ml acid mixture of conc. HCl, HF and HNO_3 acid, and placed in an oven at 180°C for 1 h[6]. Digestion for determination of Pb was carried out in medium of 0.1 M EDTA to suppress interference of phosphate and fluoride. On completion of digestion, all samples were made up to 100 ml using deionized and double distilled water. Similarly, filter papers containing PM samples were also digested and digested samples were made up to 50 ml.

Chemical Analysis

Digested samples of PM and RTWs were analyzed for Pb, Cr, Cd, Co and Ni, atomic absorption

Table 4—Correlation coefficient values between average concentration of element in respiratory tract and personal PM_5 samples

Elements	Category-A			Category-B			Category-C		
	1	2	3	4	5	6	7	8	9
Pb	12.46	0.36	0.94	6.09	0.27	0.97	2.50	0.09	0.98
Cr	6.54	0.04	0.41	8.45	0.09	0.91	13.23	0.21	0.91
Ni	3.40	0.02	0.73	4.12	0.07	0.99	8.10	0.08	0.46
Co	0.62	0.01	0.19	0.59	0.03	0.48	0.97	0.05	0.69
Cd	-	-	-	0.05	0.02	0.56	0.21	0.03	0.94

1-Average conc. of toxic metals in RTW samples; 2-Average conc. of toxic metals in personal PM_5 samples; 3-Correlation coefficient values (r); 4-Average conc. of toxic metals in RTW samples; 5-Average conc. of toxic metals in personal PM_5 samples; 6-Correlation coefficient values (r); 7-Average conc. of toxic metals in RTW samples; 8-Average conc. of toxic metals in personal PM_5 samples; 9-Correlation coefficient values (r)

spectrophotometrically[7,8]. Microsoft Excel-2000 did statistical analysis of data. Chemical analysis is presented for elements in PM (Table 2) and RTWs (Table 3). Correlation coefficients were also calculated (Table 4).

Result and Discussion

Average personal PM_5 levels for category C (31.1 μg/m^3) is about 2.6 times higher than category B (13.1 μg/m^3) and 5 times higher than category A (5.9 μg/m^3), indicating greatest risk associated with category C, which belongs to housewives who spends > 95% of their time indoors (Table 2). Indoor PM concentrations have been reported to be higher (5-7 times) than outdoor PM concentration[8-10]. Infiltration factor is equilibrium fraction of ambient PM that is found indoors. Infiltration factor (slope) and intercept values have been reported to be 0.43 and 0.9 respectively for Baltimore study[9-11]. Almost similar values of infiltration factor and intercept for Fresno-winter have been reported as 0.25 and 4.4 respectively and for spring 0.49 and 3.0[12]. In present study, higher personal PM_5 levels for category C than category A indicates same trend.

Any significant correlation between personal exposure to PM and age or sex of the subjects could not be established. Like subject number A_6 and C_4 are of same sex and age but their personal exposure levels are much different, 4.3 and 9.3 μg/m^3 respectively. Similar examples are subject number B_4-B_5 and A_7-C_7. Personal exposure to PM is found greatly influenced by participant's personal activity and life style[1,5,9-11].

Average Pb concentrations in personal PM samples are higher in category A as compared to categories B and C. Concentrations of other elements (Cr, Ni, Co and Cd) in personal PM samples are higher in category C than categories A and B. Order of occurrences of PM toxic-load is: category A, Pb > Cr > Ni > Co > Cd; category B, Pb > Cr > Ni > Co > Cd; and category C, Cr > Pb > Ni > Co > Cd. Higher PM concentrations and almost similar order of occurrences of these metals in ambient PM around same steel plant environment have already been reported[13-15].

Absorption of elements to the surface of respiratory tract depends on solubility of toxic load in water. Deposition trends of metals, having different solubility tendencies, are different in respiratory tract than personal PM toxic load. Cd has shown least tendency towards depositions in respiratory tract and could not be detected in most of the samples. A good positive correlation (Table 4) has been found between average concentrations of toxic load found in personal PM samples and RTW samples. Source of toxic-load in RTW is through personal exposure to PM found in present industrial environment.

Conclusions

Personal exposure to PM is greatly influenced by participants' personal activity and life style. Different toxic elements have different deposition tendencies observed in selected humans as subjects. Co and Cd were in same order in respiratory tract as well as in personal PM samples but other elements (Pb, Cr and

Ni) have different orders. Pb and Cr showed better correlation than Co and Cd. High risk is associated with housewives who spend their time (> 95%) indoors.

References

1 Third external review draft of air quality criteria for particulate matter, **vol I & II** (Environmental Protection Agency) 2002.

2 Kim C S & Kang T C, Comparative measurement of lung deposition of inhaled fine particulate in normal subjects and patients with obstructive air-way disease, *Am J Resp Criti Care Med,* **155** (1997) 899-905.

3 Rastogi S K, Behari V, Mathur N & Pangtay B S, Effects of air pollution on the respiratory morbidity and pulmonary function impairment in the Delhi based population, *Indian J Environ Protec,* **17** (1997) 826-832.

4 Roosli M, *Spatial variability of air pollutants in the basel area and carcinogenic and non-carcinogenic health risk,* Ph D Thesis, University of Basel, Switzerland, 2001.

5 Dockery D & Pope A, Epidemiology of acute health effects: summery of time-series studies, in *Particles in air: concentration and health effects,* edited by R Wilson & J Spengler (Harvard University Press, Cambridge, USA) 1996, 123-147.

6 Richard J, Thomson B, George M & Lezzy P, Analysis of selected elements in atmospheric particulate matter, Atom *Absorpt News Lett*, **9** (1970).

7 *Flame atomic absorption spectrometry-Analytical methods, Varian Techtron Publication No. 85-10000-00* (Varian Publication, Mulgrave Victoria, Australia) 1989.

8 Van Loon J C, *Analytical Atomic Absorption Spectroscopy for Selected Metals* (Academic Press, New York) 1980, 60-70.

9 Williams R, Creason J, Zweidinger R, Watts R, Sheldon L & Shy C, Indoor, outdoor, and personal exposure monitoring of particulate air pollution: the Baltimore elderly epidemiology-exposure pilot study, *Atmos Environ*, **34** (2000) 4193-4204.

10 Williams R, Suggs J, Creason J, Rodes C, Lawless P, Kwok R, Zweidinger R & Sheldon L, The 1998 Baltimore particulate matter epidemiology-exposure study: part 2. Personal exposure assessment associated with an elderly study population, J *Exposure Anal Environ Epidemiol,* **10** (2000) 533-543.

11 Williams R, Suggs J, Zweidinger R, Evans G, Creason J, Kwok R, Rodes C, Lawless P & Sheldon L, The 1998 Baltimore Particulate Matter Epidemiology-Exposure Study: part 1. Comparison of ambient, residential outdoor, indoor and apartment particulate matter monitoring, *J Exposure Anal Environ Epidemiol,* **10** (2000) 518-532.

12 Rodes C E, Lawless P A, Evans G F, Sheldon L S, Williams R W & Vette A F, The relationships between personal PM exposures for elderly populations and indoor and outdoor concentrations for three retirement center scenarios, *J Expos Anal Environ Epidemiol,* **11** (2001) 103-115.

13 Sharma R K & Pervez S, Spatial and seasonal variability of ambient concentrations of particulate matter around an integrated steel plant: a case study, *J Sci Ind Res,* **62** (2003) 838-845.

14 Sharma R K & Pervez S, Respiratory tract contamination with selected toxic elements in a slag based cement plant environment in Central India- A need of global concern, *J Sci Ind Res,* **63** (2004) 462-465.

15 Sharma R K & Pervez S, Study of spatial variation and enrichment of selected elements in ambient particulate around an integrated steel plant in central India, *Indian J Environ Prot,* **24** (2004) 442-452.